Kazuo SUZUKI*: **Biosystematic studies of Japanese *Epimedium* (Berberidaceae) (1). Variation of the populations in Shikoku (Part 1)**

鈴木和雄*: 日本産イカリソウ属（メギ科）の種生物学的研究
(1) 四国における集団の変異（第1部）

Epimedium L. is one of the temperate plant genera which extends from Asia to the Mediterranean region. In Japan, it is distributed from southern Hokkaido to Kyushu and is partly cultivated for horticultural and pharmacological purposes. Taxonomy of Japanese *Epimedium* has been subjected to studies by various workers (Makino 1909, 1931; Koidzumi 1932, 1936, 1938, 1939; Maekawa 1932, 1955; Stearn 1938; Nakai 1944, 1953; Ohwi 1953; Yamanaka 1953a; Shimizu 1960; Kitamura & Murata 1962). Maekawa (1955) has attempted to evaluate the relative importance of the diagnostic morphological characteristics from a phylogenetic point of view. Histological characteristics of a leaf have been examined in relation to some taxonomic problems of *Epimedium* in Kyushu (Shimizu 1960).

In spite of the works mentioned above, various taxa of Japanese *Epimedium* still do not seem to be adequately understood. As to the delimitation of several species, there are considerable disagreements of opinions among recent authors (Shimizu 1960; Kitamura & Murata 1961). Individuals with an aberrant character-combination which more or less deviates from diagnoses of the proposed species are occasionally encountered in examining herbarium specimens. My preliminary field observations have shown that the populations are sometimes remarkably variable and that intergradations would be real among the populations of some related species.

It is known for long that interspecific sterility barriers are only weakly developed in *Epimedium* (cf. Stearn 1938; Maekawa 1955). The occurrence of natural hybridization has been suggested between various taxa, and several named plant groups have been suspected to represent hybrid derivatives from some interspecific crossing (Stearn 1938; Maekawa 1955; Shi-

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mizu 1960; Kitamura & Murata 1961). Cytological studies of Japanese *Epimedium* (Koyama 1965; Suzuki unpubl.) have shown that diploids (2n=12) are predominant in Japanese *Epimedium* and their karyotypes are not variable.

With the above circumstances in mind, attempts have been made to analyze populations of Japanese *Epimedium*. The main questions asked are: (1) Is the occurrence of the individuals which can not be adequately referred to the taxa recognized in current taxonomic treatments related to hybridization? (2) Are there populations discernible as a hybrid swarm? (3) Are there interspecific gradations at the population level which would be connected with hydridization? It should be noted that plants of *Epimedium* are distinct in individuality and usually form a well-defined population.

In the present paper are reported the results obtained from the populations of Shikoku, where the following four "species" are known to occur (cf. Shimizu 1960; Yamanaka 1953a, b, 1964; Yamanaka & Morishita 1956a): *E. diphyllum* Lodd., *E. grandiflorum* C. Morr. (*sensu lato*), *E. kitamuranum* Yamanaka and *E. trifoliatobinatum* Koidz. A taxonomic revision of these entities would become necessary in the future, and they are here tentatively treated as "species" as a matter of convenience.

Materials and Methods The known localities of *Epimedium* in Shikoku are not numerous, and my field trips were arranged so as to cover them as far as possible and also to find out new localities. As a result, population samples were obtained from 23 localities indicated in Fig. 1. Table 1 shows the outline of the habitat and size of each population, together with the sample size. Sampling was made over the whole range of a population, except for two populations (4 and 20 in Fig. 1 and Table 1) which were too large to be surveyed in entirety. In the majority of the populations, more than 20 plants were sampled. But, only five to 12 individuals could be collected in five populations (1, 3, 7, 9 and 15) because these populations were very small in size. The population samples are preserved as dried specimens in MAK.

Besides the above samples, five living plants from Isl. Okinoshima (Kōchi Pref.) were utilized. These plants were transplanted to the Makino Botanic Garden, Kōchi City and to a private garden of Mr. T. Abe, Tokushima Pref.. Unfortunately, it was not possible to get a population sample or a living plant from 13 sites (solid circle without numeral and solid triangle

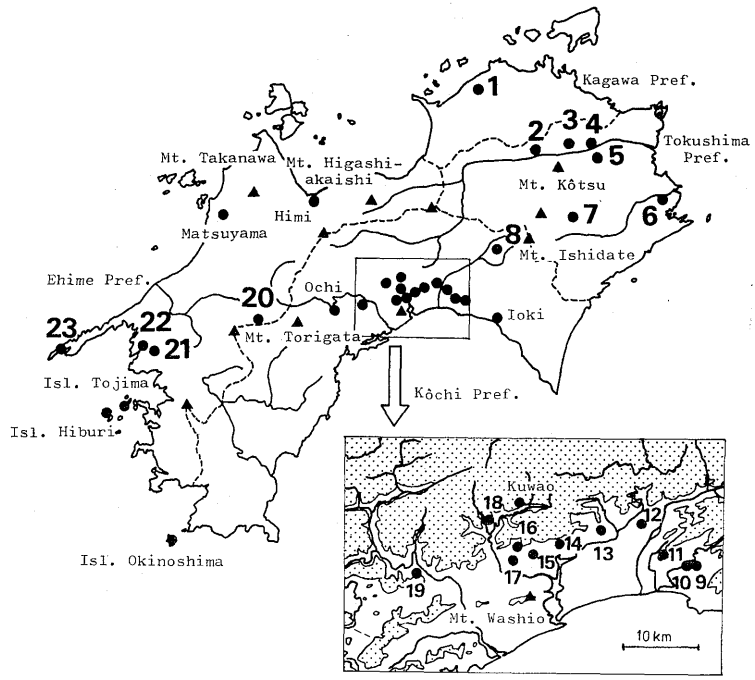

Fig. 1. Locations of the 23 populations (solid circles with numerals): 1, Mt. Iino; 2, Koboshi; 3, Masahiro; 4, Kirihata; 5, Tōzenji; 6, Nishikata; 7, Takano; 8, Go-ōdō; 9, Kagami-A; 10, Kagami-B; 11, Sako; 12, Aburaishi; 13, Okō; 14, Ikku; 15, Jinzenji; 16, Engyōji; 17, Fukui; 18, Sadanaga; 19, Funakoshi; 20, Ōnogahara; 21, Yamada; 22, Izumi; 23, Misaki. (cf. Table 1). For other symbols refer to the text.

in Fig. 1) where occurrence of *Epimedium* has been recorded in the literature or as herbarium specimens: Tokushima Pref.: Mt. Kōtsu; Kōchi Pref.: Mt. Ishidate, Ioki, Ochi, Mt. Washio, Kuwao, Mt. Torigata; Ehime Pref.: Mt. Higashi-akaishi, Himi, Mt. Takanawa, Matsuyama, Isl. Tojima, Isl. Hiburi. Sites on Mt. Higashi-akaishi and Mt. Torigata were recorded in the literature (Yamanaka 1959b, 1964), but no specimen from these two sites was available. Specimens from the other 11 localities, which could be located in certain herbaria in Japan (KYO, MAK, TI and TNS), were used in the present work as additional materials.

The following characteristics were adopted to construct scatter diagrams which would represent a composition of a population: degree of development

Table 1. Population samples of *Epimedium* in Shikoku.

Locality	Population size* and habitat (altitude**)	Number of individuals collected
1. Kagawa Pref., Mt. Iino	Small; slope, edge of pine forest, relatively dry	5
2. Tokushima Pref., Koboshi	Medium; foothill, edge of copse, relatively dry	20
3. Tokushima Pref., Masahiro	Small; foothill, bamboo forest, relatively dry	12
4. Tokushima Pref., Kirihata	Large; foothill, sparse forest, relatively dry	29
5. Tokushima Pref., Tōzenji	Medium; foothill, sparse forest	24
6. Tokushima Pref., Nishikata	Medium; foothill, conifer plantation, relatively dry	20
7. Tokushima Pref., Takano	Small; limestone cliff (800 m alt.)	8
8. Kōchi Pref., Go-ōdō	Medium; limestone slope (1000 m alt.)	18
9. Kōchi Pref., Kagami-A	Small; plain, edge of copse	11
10. Kōchi Pref., Kagami-B	Medium; plain, edge of copse	30
11. Kōchi Pref., Sako	Medium; foothill, edge of a planted conifer forest on limestone rock	18
12. Kōchi Pref., Aburaishi	Medium; foothill, bamboo forest on serpentine rock	28
13. Kōchi Pref., Okō	Medium; foothill, sparse forest on serpentine rock	26
14. Kōchi Pref., Ikku	Medium; foothill, edge of bamboo forest on serpentine rock	21
15. Kōchi Pref., Jinzenji	Small; foothill, sparse forest on serpentine rock	10
16. Kōchi Pref., Engyōji	Medium; foothill, edge of copse on serpentine rock	27
17. Kōchi Pref., Fukui	Medium; foothill, edge of bamboo forest on serpentine rock	23
18. Kōchi Pref., Sadanaga	Medium; limestone cliff (200 m alt.)	26
19. Kōchi Pref., Funakoshi	Medium; foothill, bamboo forest on serpentine rock	20
20. Ehime Pref., Ōnogahara	Very large; karst plateau with *Sasa* sp. (1300 m alt.)	24
21. Ehime Pref., Yamada	Medium; foothill, edge of copse on serpentine rock	29
22. Ehime Pref., Izumi	Medium; foothill, edge of copse on serpentine rock	24
23. Ehime Pref., Misaki	Medium; slope facing the sea	35

* small, ca. 5 m × 10 m; medium, ca. 20 m × 50 m; large, more than 50 m × 100 m.

** An altitude is indicated only for population located in the upland.

of a spur, lenght of inner sepals, hairiness of leaves, petiole length of a stem-leaf, number of serrations/midvein length of a leaflet, type of ramification to leaflets, shape of a leaflet apex. Several other features such as flower color and duration of leaves were also examined, but they were not adequate to incorporate into the diagram (*vide post*).

Two or more flowers per individual were used for measurements of spur length and inner sepal length. The density of hairs on both upper and lower surfaces of a leaf were observed in three different parts with 6.25 mm^2 of one or two leaves per individual. This examination was applied to the leaves which were assumed to be at the mature stage. All leaflets of one or two leaves per individual were examined to calculate the ratio of serration number/midvein length. The mean of measurements obtained as to the above characteristics for each individual was adopted as the representative figure.

The type of ramification to leaflets was classified into the following five categories on the basis of the modes of the first and the second ramification (geminate or ternate) of two or more leaves per individual: i, bigeminate only (Fig. 2-a); ii, first geminate and then ternate (Fig. 2-c); iii, intermediate between (a) and (c) (Fig. 2-b) and/or mixed (a) and (c) within an individual; iv, biternate only (Fig. 2-d); v, mixed (c) and (d) within an individual. The shape of leaflet apex could be classified into three types: i, obtuse (Fig. 3-a); ii, acuminate (Fig. 3-c); iii, mostly acute, intermediate between i and ii (Fig. 3-b). The symbols adopted in scatter diagrams are shown in Fig. 5.

Pollen fertility was examined by staining pollen in a cotton blue-lactophenol solution for at least 24 hours. The value for an individual was

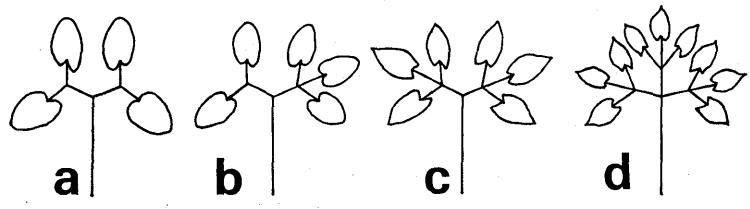

Fig. 2. Types of ramification to leaflets: a, bigeminate; b, intermediate between a and c; c, first geminate and then ternate; d, biternate.

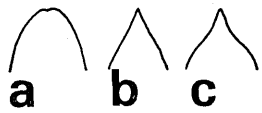

Fig. 3. Types of leaflet apices: a, obtuse; b, almost acute (intermediate); c, acuminate.

obtained by the observation of 200-500 pollen grains. The grains stained deeply and uniformly were scored as fertile.

Results *Populations referable to the representative types.* Results of morphological examinations have shown that a considerable number of the populations examined are rather stable and can be referred to one of the species currently recognized. Morphological differences of the four species which have been confirmed by the examination of the plants from Shikoku are indicated in Table 2. Fig. 4 shows their distributions within Shikoku.

E. diphyllum: A population referable to this species was found in one locality (11 in Fig. 1 and Table 1), which is situated in the lowland (100 m alt.). As shown in Fig. 5, samples from this population are morphologically not variable though a minor fluctuation was detected in the type of ramification. Herbarium specimens from Mt. Kōtsu, Ochi, Himi, Mt. Takanawa and Matsuyama are also referable to *E. diphyllum*. According to Mr. T. Abe (personal communication), the population on Mt. Kōtsu which represents the eastern limit of the distribution area of this species was located near the summit (1100 m alt.).

Table 2. Diagnostic morphological features of four "species" of *Epimedium* in Shikoku.

	E. diphyllum	*E. kitamuranum*	*E. trifoliatobinatum*	*E. grandiflorum*
Petal (spur length)	spurless		short-spured (10-16 mm)	long-spured (15-23 mm)
Inner sepal (length)	short (4-9 mm)	short (5-9 mm)	long (9-14 mm)	long (9-15 mm)
Upper surface of leaflets	glabrous	sparsely hairy	glabrous	
Lower surface of leaflets	densely hairy		hairy	glabrous
Ramification	bigeminate	first geminate and then ternate		biternate
Shape of a leaflet apex	obtuse	mostly acute (intermediate)		acuminate

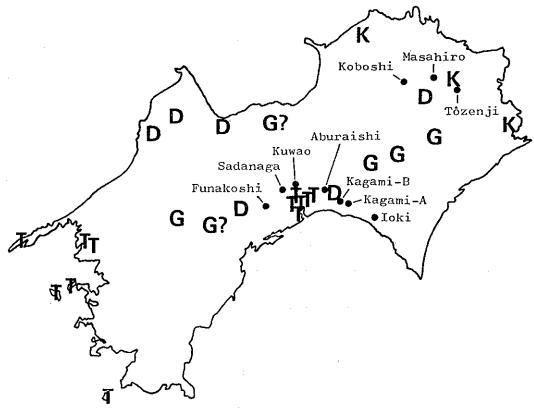

Fig. 4. Distributions of four representative types ("species"): D, *E. diphyllum*; K, *E. kitamuranum*; T, *E. trifoliatobinatum*; G, *E. grandiflorum*. Localities of the problematical populations and those of the problematical herbarium specimens (Ioki and Kuwao) are also indicated with solid circles.

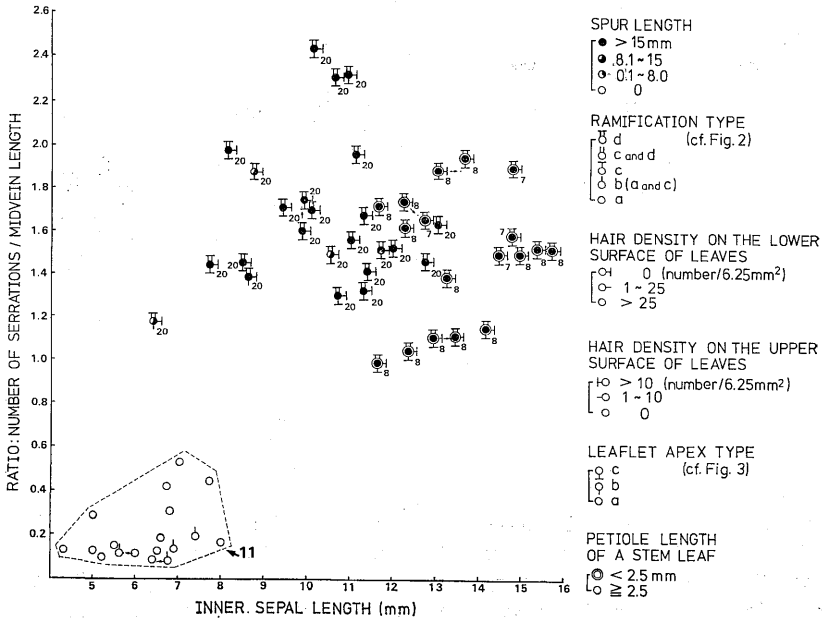

Fig. 5. Scatter diagram showing the character correlation in the collections from four populations: 11, Sako—*E. diphyllum*; 7, Takano; 8, Go-ōdō; 20, Ōnogahara—*E. grandiflorum*. The numerals inserted correspond to the population numbers in Table 1 and Fig. 1; the same in the rest of the diagrams.

E. grandiflorum: Three populations were found to be referable to this species (7, 8 and 20 in Fig. 1 and Table 1). They were all from the uplands (800-1300 m alt.). Morphological features of the samples from these populations are indicated in Fig. 5, which clearly shows that they are related to one another though somewhat variable in inner sepal length and the relative frequency of serrations of leaflets. Nevertheless, two types could be discerned in this species. One of them consisted of two populations in eastern Shikoku (7 and 8) and was characterized by a very short petiole of a stem-leaf (less than 2.1 mm). A herbarium specimen from Mt. Ishidate, which is also located in eastern Shikoku is identical with this type. The other type represented by the Ōnogahara population (20) in western Shikoku was distinctive in having an apparently longer petiole (4.4-46.4 mm in range, 21.5 mm in the mean and 11.5 mm in SD).

E. kitamuranum[1]: Three populations from northeastern Shikoku (1, 4 and 6 in Fig. 1 and Table 1) were composed of the individuals which are

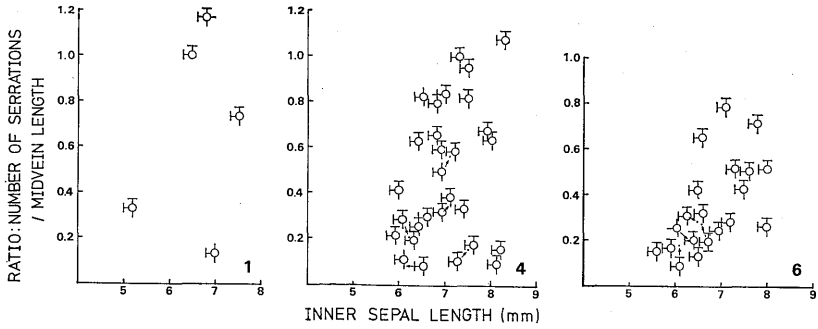

Fig. 6. Scatter diagrams showing the character correlation in the collections from three populations: 1, Mt. Iino; 4, Kirihata; 6, Nishikata—*E. kitamuranum*. Symbols are the same as in Fig. 5.

1) In his original description of *E. kitamuranum*, Yamanaka (1953a) wrote as follows: "Foliola····, supra viridia infra glaucescentia, utrique minute pilosula mox glabrescentia." Yamanaka (personal communication) recently commented, however, that this part of his description must be amended, because a closer examination had shown the presence of some hairs on both surfaces of the leaf at the mature stage. I have also confirmed this in the type specimen (Yamanaka coll.) of *E. kitamuranum* preserved in KYO.

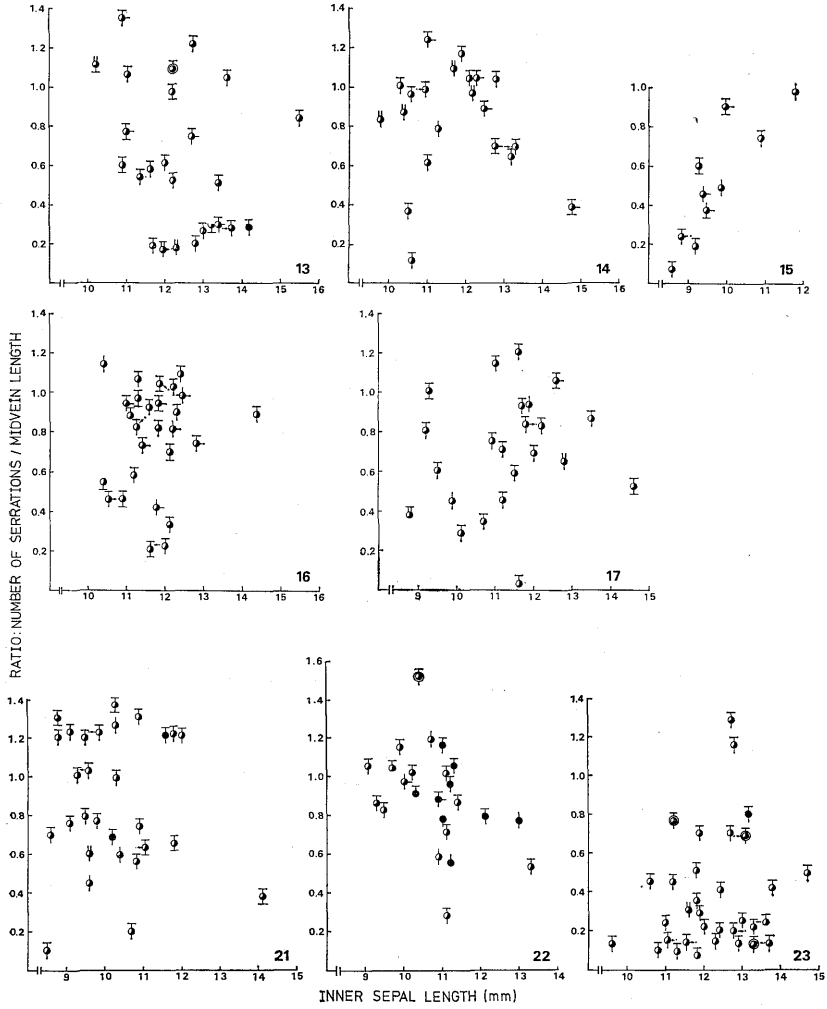

Fig. 7. Scatter diagrams showing the character correlation in the collections from eight populations: 13, Okō; 14, Ikku; 15, Jinzenji; 16, Engyōji; 17, Fukui; 21, Yamada; 22, Izumi; 23, Misaki—*E. trifoliatobinatum*. Legends for symbols as in Fig. 5.

throughout referable to *E. kitamuranum*. They were all found on relatively dry foothills in the lowlands (cf. Table 1). As indicated in Fig. 6 (1, 4 and 6), plants from these populations morphologically resemble *E. diphyllum* but

are different in having the hairy upper surface of a leaf, the c-type of the ramification and the b-type leaflet apex except a few collections.

E. trifoliatobinatum: Eight populations (13, 14, 15, 16, 17, 21, 22 and 23 in Fig. 1 and Table 1) were found to represent a relatively homogeneous assemblage which can be referred to *E. trifoliatobinatum*. The transplants from Isl. Okinoshima and herbarium specimens from Isl. Tojima and Isl. Hiburi, Ehime Pref., and Mt. Washio, Kōchi Pref., were also referable to this species. It is remarkable that almost all of these populations are located on serpentine rocks in the foothills (cf. Table 1). As evident from Fig. 4, the populations are situated separating into two geographical groups, central and western Shikoku. Morphological studies showed, however, that no differentiation was discernible between these two groups of populations (Fig. 7, 13-17 vs. 21-23).

Besides the characters appearing in Table 2, by which the four representative types described above are separated, several morphological features were found to be variable but not significant taxonomically. In various populations of *E. diphyllum*, *E. trifoliatobinatum* and *E. grandiflorum*, a few individuals with somewhat purplish or reddish flowers were observed in mixture with the individuals having white or pale creamy-white flowers. The hairs on the lower surface of leaves of *E. trifoliatobinatum* and *E. kitamuranum* were generally longer than those of *E. diphyllum* (cf. Fig. 9), but the distinction was not evident. Appressed hairs, besides the ordinary erect hairs, were sometimes observed in *E. kitamuranum*, but the presence of this type of hairs could not be connected with a taxonomic grouping. The same was true of the presence of bienial leaves and the white lower surface of leaves. (to be continued)